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Optical Disk based Acquisition System (ODAS)
Description and Report
Following the First Deployment
during the Prudhoe Bay Experiment
Spring 1987 (PRUDEX)

by

Keith von der Heydt

November 1987

Technical Report

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Approved for Distribution:

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Department of Ocean Engineering

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Abstract

  — This is a report on the use of one vendor's optical disk system for the archiving of data in the field. Two Optimem 1000 units are part of an acquisition system used by the Arctic acoustics groups at Woods Hole Oceanographic Institution and the Massachusetts Institute of Technology during an ice-camp based experiment conducted during March of 1987 north of Alaska, (PRUDEX). Data recording and disk directory formats developed specifically for continuous recording of multichannel digital data are described as well as the acquisition system itself. A brief overview of available optical disk drive systems and their applicability to use in the field for storage of large volumes of data is given.

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Introduction

This report is intended to present information on experience to date of the Arctic Acoustic Group at WHOI with a recently assembled data acquisition system used to record acoustic data from an array of sensors. Optimem 1000 "write once-read many" (WORM) optical disk drives are used to archive data in the field. Information is given on the form and functionality of the system, the disk and file formats developed for this purpose, and more specifically, our thoughts on the reliability of Optimem's drive, following a 3 week field effort using this system in the spring of 1987.

1. Comments on State of Optical Disk Technology

Recent developments in the field of laser disk technology have made it practical to store large amounts of digital data on optical platters, as compared to standard 9-track tape. This augurs well for experimental efforts with requirements to acquire and store large quantities of data for subsequent processing elsewhere. Current "writable" optical disk technology is limited to write-once-read-many, or "WORM", capability, though erasable media is on the horizon. One manufacturer, Verbatim, will soon offer a 3 1/2 inch read/write optical drive available with about 50 mbytes storage. A number of manufacturers currently offer a variety of drives, using different size platters, single and double sided, with different capacities, usually using media from one source only. Media standardization has yet to be embraced which can be worrisome for the new user. As expected of an emerging technology, one is motivated to select the "right" vendor, i.e. one that is going to be around for the long haul, and not render a commitment to the technology obsolete or at best, difficult to support. Also, storage densities can be expected to increase significantly as this technology matures.

WORM disk drives use a precisely focused, low power laser to write and subsequently read data. When writing, the laser power is increased to either burn a pit or make a bubble in the media, depending on the system. Reading is accomplished by sensing the level of reflected light from the disk using lower laser power, as it passes over the bubbles or pits. Densities vary depending on whose system is used. The Hitachi and Sony 12" double sided platters store 1.3 gigabytes ($10**9$) per side whereas the Optimem platters store 1.0 gigabytes per side. Currently, 5-1/4" platters can store 120 to 400 megabytes ($10**6$) per side, though a 500 megabyte version will be available shortly from at least one source, Information Storage Inc.(ISI). For comparison, a 2400 foot, 1600 BPI 9-track tape can store between 30 and 40 megabytes, suggesting between 50 and 80 reels equivalent storage on a 12" double sided optical platter. Economically, media for optical disks already offer a significant improvement over tape. A good price for 2400 foot Quantum tape is about $14., and small quantities of double sided disks from Optimem are $422. ($360 for Sony's). This is nearly a factor of 2 improvement in $ per megabyte of storage.

Single unit prices for the 12" platter Optimem drive with SCSI controller and EDAC controller are nearly $13k. The ISI 5-1/4" drive with 120 megabytes per side is about $2500.

Error detection and correction (EDAC) is a significant aspect of optical disk technology. The raw error rate of present optical media is about 1 in $10**4$, rather unacceptable. In the case of the Optimem drives, EDAC improves this level to about 1 part in $10**10$ without retries enabled and 1 part in $10**12$ with a maximum of 5 retries. Retries on reads on the Optimem are always enabled unless explicitly disabled. This means that on a double sided platter, the probability of a single unrecoverable bit error is about .02. This rate compares favorably to tape. Optimem also gives the specification of 1 undetected error in $10**16$. The information overhead to achieve this level of data integrity is about 9%.

To date, there is no standard interface for optical drives. Hitachi uses

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the IEEE 488 interface whereas Optimem, Sony, ATG, OSI and others are using the SASI/SCSI interface, (SASI=Shugart Associates System Interface and SCSI=Small Computer System Interface) SCSI is the ANSI version of SASI, ANSI X3.131-1986 and is becoming well known as an embedded mass storage interface standard.   At least one 5-1/4" source, Maximum Storage Inc, uses the ESDI interface.   All are essentially byte-serial buses with control lines and multiple device/logical unit capability, and have similar bus bandwidth of 1 to 3 mbytes/sec, depending on implementation.

Software for using optical drives is available for a select few systems. At least one company (KOM USA) will supply an optical disk drive, a host adapter, (the hardware interface to a SCSI drive), and system level driver for VAX machines running VMS.   A few sources exist for IBM compatible packages of a drive(s), host adapters, and software driver,(Optimem,ISI,MSI, & others). The list of SCSI host adapters is long and many machines can be accommodated. Software is still a difficulty for many non-DEC or IBMpc and compatible machines. Note that for the system described in this report, no equivalent software is available as continuous high speed storage is required by few users.   Some small machines are turning up with built in SCSI interfaces such as Apple's Mac.

Some systems integrators consider the Sony drives to have the best quality, reliability and ease of use, though they are slow.   The Optimem seems to be one of the fastest with the capability of nearly .5 megabyte/sec sustained transfer rate, though this isn't particularly fast compared to large capacity conventional read/write drives.

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2. WHOI Optical Disk based Acquisition System, (ODAS)

2.1 Objectives

Our interest in optical disk drives developed during our quest for cheaper, more dense storage for our acoustic array data acquisition experiments. Recently, for another project, (ARAMP), we have begun to work with the ISI drive which has a standard, full height 5-1/4 inch footprint and can be either single or double sided. Initial tests indicate that this drive and its media may be operable at very low temperatures, well below 0 degrees C, making it useful for ocean and possibly Arctic instrumentation applications.

Archival data storage at high rates is one of our primary interests in optical disk technology, so the write once capability is ideal. Though the term "WORM" implies write once capability, it is in fact possible to write over existing data leaving garbage as a result, or more accurately, the logical "OR" of the multiple writes. Fortunately, there are a couple levels of protection against this occurance. Aside from cost and density advantages over 9-track storage, the optical disks offer relatively fast random access storage which is an important factor during processing. Though in comparison, large hard disks have somewhat faster access times, (factor of 4-5) such as DEC RA81/82 technology, the optical drives are a dramatic improvement in stored data accessibility over tape.

There are other less expensive methods for storing large amounts of data such as DigiData's "Gigastore" which is essentially a premium quality VHS drive mechanism using VHS tape cassettes. This unit costs about $5000 and can store about 4 gbytes of data on a cassette. It comes with a Pertec interface and is aimed at the large disk backup market, though under some conditions it could be used as a data recording device. There are other sources of VHS cassette based storage designed specifically for data acquisition, which are less expensive, battery powered replacements for large FM analog recording systems. These systems to date have limited flexibility as they are essentially a streaming tape that is not easily used in a start/stop mode. Also, they have been cumbersome to use when it comes to processing the recorded data, as random access is very slow, but they do offer dense, cheap storage. For applications where battery power is required, this system may be a good alternative. We have chosen the optical disk based system for its lack of sampling rate constraints (only limited by the maximum average storage bandwidth), its speed, and random accessability.

2.2 Description of ODAS

ODAS is designed to be able to acquire data at aggregate rates limited only by the maximum average writing rate of the Optimem disk drive, approximately 480 kbytes per second. We typically store a data value in a 2-byte format, the 13 least significant bits comprising a 2's complement, mantissa and the 3 most significant bits comprising a gain word. This is the format of output from our Gain Ranging Amplifier (GRA) system. A number we refer to as "channel-bandwidth-product", the product of the number of channels

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sampled, the sample rate and the number of bytes per sample (2), is the only inherent limitation on acquisition of sampled signals. It must on average always be less than the maximum sustained writing rate of the storage device.

As used during PRUDEX, ODAS, figure 1, consisted of an acquisition microcomputer, an Optimem disk drive, a gain-ranging filter/amplifier/digitizing system (GRA), and a stable time base. Acquisition software is written in the "C" language with the data input routine written as an interrupt procedure in assembly language. During this first use of the system, the channel-bandwidth product was constrained to be considerably less than the 480 kb/s due to the use of programmed I/O for the incoming data. This limitation has been eliminated with the completion of an "intelligent" buffer card that is the interface to the GRA. This interface consists of a megabyte of dual port RAM that can be accessed as part of system memory space by the SCSI host adapter that transfers data to the Optimem drive. A ram based sequencer on the interface inputs data from the GRA's over a 16 bit data bus, and an 8 bit channel address bus. This sequencer is configured by the host processor at runtime and is flexible enough to permit transfers from data sources other than our GRA's.

The microcomputer used is an Intel 310, 8086 based machine on Multibus, running generic MSDOS. Its capability lies with the multi-master aspect of Multibus which permits continuous acquisition at data rates in excess of the disk's maximum. The simplicity of a single user system minimizes the difficulties of timing issues as well.

An NCR SCSI host adapter, ADP32-01 is used with the Optimem drives. This card becomes a bus master during SCSI operations, allowing it to handle host-packaged SCSI commands via a system memory based mailbox structure. This minimizes the complexity of driver level software. The architecture of the GRA interface is such that incoming data passes across the bus only once on its way to the disk, optimizing use of the Multibus bandwidth.

The megabyte of buffer space is divided into 4 equal segments allowing data to be written to the disk in blocks of up to 256 kbytes. The interface is programmed to interrupt the host processor when a buffer is full (depending on the number of channels being recorded), at which time a SCSI transfer to the optical disk is initiated. Each time a "buffer full" interrupt is received, real-time to the millisecond is latched and held until the host has a chance to load it and other information into a data header record which is written in front of each data record.

There is an IRIG B time code reader on the GRA interface that is used to synchronize the acquisition clock to the millisecond. A 1 megahertz input, derived from a rhubidium oscillator is used as the system timebase, including that of the IRIG code generator, to provide a stable reference for any foreseeable acquisition requirement. The rhubidium and the IRIG generator are powered from an uninterruptable, battery backed supply to eliminate real-time loss from power outages normally experienced during generator maintenance in the field.

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2.3 Discussion of Optimem Optical Drive Usage

2.3.1   Commands

The Optimem drive can be purchased either in Master or Slave configurations. As an SCSI bus master, a drive includes an SCSI controller, and an error detection and correction (EDAC) Controller. As a slave, drives do not have SCSI or EDAC controller cards. Up to 7 slave drives can be connected in parallel with a Master drive on the Optical Disk Interface (ODI) bus.

Storage available per platter side is 1.024 gbytes, comprised of 1000000 - 1024 byte blocks or sectors. Logical blocks have physical addresses (LBA's) of 0 through 999999 though the disk is considered to have 40000 tracks of 25 sectors each. In fact, the blocks are contiguous since the tracks are spiraled so it is really one long sequence of sectors.

The Optimem supports a large subset of the standard set of SCSI commands, (SCSI was designed to handle a wide variety of read/write devices). The basic operations are:

READ
WRITE
VERIFY

with an assortment of other commands to set operating modes, get status information and initiate various diagnostic procedures. WRITES can be done "blindly" or with verification or with both verification and automatic relocation. Verification of written data is done by writing up to 4 blocks of data, (current FIFO buffer size is 4kb), letting the disk rotate past the next 21 blocks, then reading the blocks just written and comparing them with what should have been written. Relocation occurs when during a WRITE & VERIFY process, the VERIFY process finds that data in a sector does not compare with what was supposed to have been written. If the comparison implies an error (this is all done with the full power of the EDAC processor), then the disk controller moves to the relocation area (18 full tracks before LBA 0) and again writes the sector. This process will be attempted up to 4 times in the relocation area.   When a sector is read and uncorrectable blocks, (UCB's) detected, if relocation is enabled, the controller moves over to the relocation area and looks for a sector that is tagged with the same LBA, and reads that one. Note that this doesn't work for blocks that already have something written, in which case status information is returned indicating a non-blank sector. READ can be done with or without relocation checks.

Blank checking, which we have done on disks to be used for data recording, is accomplished by first reading the sector to check for a UCB and then searching the WRITE CHECK field of the sector for non-zero bits. This process takes about 35 min for an entire side, about the same as to fill a side of the disk at the maximum continuous writing rate. The resultant table of non-blank sectors, if any, is recorded in the subsequently written disk header for later use.

The drawback acompanying use of verification and relocation is a

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significant speed penalty. The Optimem performs verification as a separate operation after the write operation, in 4k byte chunks (4k is the size of the controller's buffer). The write rate possible with verification is at best 1/12 of the write rate without verification. We write data without verification and anything else such as directories and header files with verification and relocation enabled. Optimem now offers a 64k byte buffer in their drives that will decrease this penalty substantially.

2.3.2   Disk Format

        After researching directory and file formats on write-once media, we have devised the following scheme for use with the Optimem disks.

        An important consideration was the fact that the disk is write-once media with a large amount of data at stake and the possibility of a few unusable sectors sprinkled about the disk. This configuration duplicates the directory information associated with each file. Files are written starting at the low numbered LBA's. Directory information for each file resides at the sector preceeding the file with continuation directory sectors possibly at the end of the file if necessary. Using a complete sector for a single files' directory may be slightly wasteful of space but it isn't significant. The same directory information is written starting at the upper end of the disks 1000000 blocks and working downward, towards the area being filled with files. We also store directory information on a floppy disk to give a third chance at recovering data from a disk that has suffered errors in both directory areas for a given file. This method of writing directory information on write-once media offers a satisfactory probability of recovering data on a disk since the 2 areas for directory information for a given file are always in physically different areas. Also, except when errors in the "concentrated" directory area prevent it, the complete directory is accessible fairly quickly. Again, time is never critical when writing directory areas so the write/verify with relocation method would always be used, maximizing directory integrity. This scheme could be modified slightly to permit use of leftover space in directory sectors for file data but since data files are likely to be quite large it doesn't matter. The following describes the usage of disk space:

Logical block address
LBA0

```
        !-----------------------------------!
        |         disk header using         |
        |         one or more blocks        |
        !-----------------------------------!
        |         FILE 0 DIRECTORY          |
        |            ENTRY                  |
        !-----------------------------------!
        |            FILE  0                |
        |                                   |
```

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```
                 |                                  |
                 |            "n0" BLOCKS           |
                 |----------------------------------|
                 |      FILE 0 DIRECTORY ENTRY      |
                 |     CONTINUATION IF NECESSARY    |
                 |----------------------------------|
                 |        FILE 1 DIRECTORY          |
                 |             ENTRY                |
                 |----------------------------------|
                 |                                  |
                 |            FILE  1               |
                 |                                  |
                 |           "n1" BLOCKS            |
                 |----------------------------------|
                 |      FILE 1 DIRECTORY ENTRY      |
                 |     CONTINUATION IF NECESSARY    |
                 |----------------------------------|
                 |        FILE 2 DIRECTORY          |
                 |             ENTRY                |
                 |----------------------------------|
                 |                                  |
                 |            FILE  2               |
                 |                                  |
                 |           "n2" BLOCKS            |
                 |----------------------------------|
                 |      FILE 2 DIRECTORY ENTRY      |
                 |     CONTINUATION IF NECESSARY    |
                 |----------------------------------|
                 |                                  |
                 |          AND SO FORTH            |
                 |                                  |
                 |              |                   |
                 |                                  |
                 |              |                   |
                 |                                  |
                 |              |                   |
                 |                                  |
                 |              |                   |
                 |                                  |
                 |              |                   |
                 |              |                   |
                 |----------------------------------|  These sectors
                 |                                  |  are dups of
                 |     FILE n DIRECTORY ENTRIES     |  those shown
                 |                                  |  earlier of the
                 |              |                   |  same label
                 |                                  |
                 |              |                   |
                 |                                  |
                 |----------------------------------|
                 |     FILE 2 DIRECTORY ENTRIES     |
                 |----------------------------------|
                 |     FILE 1 DIRECTORY ENTRIES     |
                 |----------------------------------|
                 |     FILE 0 DIRECTORY ENTRIES     |
                 |----------------------------------|
                 |           DISK HEADER            |
   END OF DISK   |----------------------------------|
```

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2.3.3   Description of disk Header:

The disk header consists of the following information, but it is not inherently limited to this. All pointers are 4 byte binary or "longs" in 16 bit machine "C" and "ints" in 32 bit machine "C". Incompatiblities in the actual byte-wise format of these values between an 8086 based machine and a VAX have not been examined. It may be academic since the data word format is non-standard and any routines written to read these disks on a VAX could be made to accommodate long vs. int incompatibilities.

DISK HEADER SECTOR FORMAT

```
byte 0       |-----------------------------|
             |    disk header key, "ODHD"   |
             |        4 ASCII bytes         |
             |-----------------------------|
             | disk S/N (as written on disk |
             |  pack cover), in ASCII with  |
             |        leading zeroes        |
             |    NNNNNNNNNNNNNNNNN          |
             |-----------------------------|
             |     date in MSDOS format     |
             |         4 bytes              |
             |-----------------------------|
             |     time in MSDOS format     |
             |         4 bytes              |
             |-----------------------------|
             |   start of compact dir area  |
             |-----------------------------|
             |     start  of file area      |
             |-----------------------------|
             |   total # non-blank sectors  |
             |     when disk was unused     |
             |      4 byte unsigned int     |
             |-----------------------------|
byte 36      |      non-blank sector table  |
             |   consisting of LBA pointers |
             |   4 bytes each, unsigned ints|
             |                              |
             |              |               |
             |                              |
             |              |               |
             |                              |
             |              |               |
             |                              |
             |  unsued 4 byte VALUES set to |
             |             0x00             |
             |-----------------------------|
byte 1016    |    4 bytes set to 0x00 if no |
             |       continuation sector,   |
```

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```
          !    otherwise points to      !
          !    continuation sector       !
          !----------------------------!
byte 1020 !    disk header key VALUE,    !
          !    ASCII "ODHD", 4 bytes     !
          !----------------------------!

sector boundary
```

2.3.4   File Directory Entries

File directory entries have a structure similar to the disk header. File
directory entries always begin with the directory sector key, "ODIR", in 4
ASCII bytes. Following the key, in sequence are: the file name in 16 ascii
bytes, the date and time in 8 bytes (MSDOS format), the total # bytes in the
file excluding filler bytes to get to the end of the last sector (4 byte
unsigned int), and a sequence of 4 byte unsigned int pairs, the first of which
points to the starting LBA of a file segment, and the 2nd of which is the
#LBA's in the segment. This is done so that a data file can be written such
that it skips over known bad areas.   All unused bytes in a file directory
sector will be written as zeroes, (same as not written). If a continuation
sector is required, the last PTR value in the sector (the next to last 4 byte
VALUE), is non-zero and points to the LBA where directory information is
continued.   In all cases, whether there is a continuation sector for the
directory entry or not, the last 4 byte VALUE is the directory entry key,
"ODIR" in ASCII.

FILE DIRECTORY ENTRY SECTOR FORMAT

```
byte 0     !----------------------------!
           !    directory key, "ODIR"    !
           !       4 ASCII bytes         !
           !----------------------------!
           !    filename, in ASCII       !
           !      space filled           !
           !        16 bytes             !
           !    XXXXXXXXXXXX.YYY          !
           !----------------------------!
           !    date in MSDOS format     !
           !        4 bytes              !
           !----------------------------!
           !    time in MSDOS format     !
           !        4 bytes              !
           !----------------------------!
           ! this entry's LBA in comp area !
```

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```
              !----------------------------------!
              !  this entry's LBA in file area   !
              !----------------------------------!
              !      total # bytes in file       !
              !     excluding "filler" bytes     !
              !       at end of last sector      !
              !        4 byte unsigned int       !
              !----------------------------------!
byte 36       !        LBA pointer to 1st        !
              !           file segment           !
              !         4 byte unsigned int      !
              !----------------------------------!
              !      # blocks in 1st segment     !
              !        4 byte unsigned int       !
              !----------------------------------!
              !    LBA pointer to 2nd segment    !
              !        4 byte unsigned int       !
              !----------------------------------!
              !                !                 !
              !                                  !
              !                !                 !
              !                                  !
              !                !                 !
              !                                  !
              !    unsued 4 byte VALUES set to   !
              !               0x00               !
              !----------------------------------!
byte 1016     !     4 bytes set to 0x00 if no    !
              !        continuation sector,      !
              !         otherwise points to      !
              !         continuation sector      !
              !----------------------------------!
byte 1020     !     directory entry key VALUE,   !
              !       ASCII "ODIR", 4 bytes      !
              !----------------------------------!

sector boundary
```
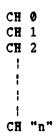
2.3.5   ODAS Data File Format

A data file consists of the following in sequence:

A FILE HEADER is normally 1 block long but may be more than 1 block and is always an integral number of blocks.

An arbitrary number m, of RECORDS, each consisting of a RECORD HEADER 1 block long and a sequence of DATA using less than or equal to k blocks for an arbitrary number of channels n, and samples p, normally the same number of samples per channel, with an integral # of sectors completely filled, computed as follows:

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$$(n*p*(bytes/sample) <= k \text{ kbytes}),$$

where k is currently limited to 256 but could be made larger depending on the total size of the GRA interface buffer.

```
                          CH 0
                          CH 1
                          CH 2
                           |
                           |
                           |
                           |
                          CH "n"
```

```
                    |---------------------------------|
                    |          FILE HEADER            |
sector boundary     |---------------------------------|
                    |        RECORD 0 HEADER          |
sector boundary     |---------------------------------|
                    |         DATA FOR CH 0           |
                    |---------------------------------|
                    |         DATA FOR CH 1           |
                    |---------------------------------|
                    |         DATA FOR CH 2           |
                    |---------------------------------|
                    |         DATA FOR CH 3           |
                    |---------------------------------|
                    |                                 |
                    |                |                |
                    |                                 |
                    |                |                |
                    |                                 |
                    |                |                |
                    |                                 |
                    |                |                |
                    |---------------------------------|
                    |        DATA FOR CH "n"          |
sector boundary     |---------------------------------|
                    |        RECORD 1 HEADER          |
sector boundary     |---------------------------------|
                    |         DATA FOR CH 0           |
                    |---------------------------------|
                    |         DATA FOR CH 1           |
                    |---------------------------------|
                    |         DATA FOR CH 2           |
                    |---------------------------------|
                    |         DATA FOR CH 3           |
```

```
        +----------------------------------+
        |               !                  |
        |               !                  |
        |               !                  |
        |               !                  |
        +----------------------------------+
        |          DATA FOR CH "n"          |
sector boundary +-------------------------+
        |          RECORD 2 HEADER          |
sector boundary +-------------------------+
        |          DATA FOR CH 0            |
        +----------------------------------+
        |          DATA FOR CH 1            |
        +----------------------------------+
        |          DATA FOR CH 2            |
        +----------------------------------+
        |          DATA FOR CH 3            |
        +----------------------------------+
        |               !                  |
        |               !                  |
        |               !                  |
        |               !                  |
        +----------------------------------+
        |          DATA FOR CH "n"          |
sector boundary +-------------------------+
        |          RECORD 3 HEADER          |
sector boundary +-------------------------+
        |          DATA FOR CH 0            |
        +----------------------------------+
        |          DATA FOR CH 1            |
        +----------------------------------+
        |          DATA FOR CH 2            |
        +----------------------------------+
        |          DATA FOR CH 3            |
        +----------------------------------+
        |               !                  |
        |               !                  |
        |               !                  |
        |               !                  |
        +----------------------------------+
        |          DATA FOR CH "n"          |
sector boundary +-------------------------+
        |               !                  |
        |               !                  |
        +----------------------------------+
```

```
                        ¦             ¦             ¦
                        ¦             ¦             ¦
                        ¦             ¦             ¦
sector boundary  ¦------------------------------------¦
                        ¦       RECORD "m" HEADER      ¦
sector boundary  ¦------------------------------------¦
                        ¦        DATA FOR CH 0         ¦
                        ¦------------------------------------¦
                        ¦        DATA FOR CH 1         ¦
                        ¦------------------------------------¦
                        ¦        DATA FOR CH 2         ¦
                        ¦------------------------------------¦
                        ¦        DATA FOR CH 3         ¦
                        ¦------------------------------------¦
                        ¦             ¦             ¦
                        ¦             ¦             ¦
                        ¦             ¦             ¦
                        ¦             ¦             ¦
                        ¦             ¦             ¦
                        ¦             ¦             ¦
                        ¦------------------------------------¦
                        ¦       DATA FOR CH "n"        ¦
sector boundary  ¦------------------------------------¦
```

Either a continuation directory entry sector or the directory entry
sector for the next file would follow the last sector of this data file.

Non data files, ASCII or otherwise end up being null filled to end of
last sector used since an unwritten byte is a null (0x00). As with a data
file, a non-data file has the file byte count in the directory entry so the
reading program knows when the end of the file is reached, i.e, no hard EOF
used

3. Comments on Optimem disk drive operation during PRUDEX

Upon return from the Prudex field experiment, data from all normally completed acquisition runs was readable by both Optimem drives in use. Subsequent to each experiment, selected segments of data from all channels were plotted in both time and frequency domains as a qualitative check. An important check of a data file is to look at the time differences between sequential blocks to be sure that no points were lost. Moveout between sensors in the array was compared to the known geometry of the array with good results. Typically 12 channels were acquired at a 1 kHz rate, though sampling rates up to 6kHz were used with a smaller number of channels.

On four occasions, during acquisition runs, the optical disk drive malfunctioned. Symptoms each time were not consistent. On two occasions, the acquisition program returned with inconclusive status information and at other times, the system simply "hung" with no status reported. Initial appraisals focused on media problems in that certain areas of some disks could not be reliably accessed. Subsequent tests indicated that in fact the media was not at fault since a second drive had no difficulties accessing or reading the questionable areas. While in the field, the offending drive was used to acquire data continuously for periods as long as 12 hours, with no problem, though on one occasion it malfunctioned immediately upon initiation of an acquisition session. This suggests the possibility that the Optimem drives are not as robust to the vibration of travel as one would hope. Identical symptoms were experienced upon return as in the field with the same drive. The unit was returned to Optimem for an upgrade and diagnosis with only minor adjustments made. They suggested that the drive was not in good order before shipment. Prior to the next field deployment, we will subject drives to travel induced vibration followed by in-lab use to attempt to learn how prevalent this problem might be. It may be that our packaging of the drives for shipment was inadequate, though we have shipped similarly delicate equipment, including magnetic disk drives, many times. Optimem routinely ships these units in simple cardboard boxes with minimal foam padding. Storage temperature specs are not a constraint and care was taken to remain within the reccommended rate of temperature change when drives were brought in from the cold to warm. Optimem suggests that the most likely source of difficulty with applications such as ours is the media and not the drive itself.

A related issue is the durability of Winchester drives, similar to those found on numerous "PC" like machines now. During this experiment, we had 3 machines running with hard disks more or less continuously in a heated but uncontrolled non-lab environment, with no problems. This of course was after the same difficult journey made by the Optimem drives. Knowing that optical heads fly considerably higher off the media than Winchester heads, one might be encouraged about the durability of the former.

There is one annoying feature of the Optimem drive from the standpoint of continuous data acquisition. At random times, the drive executes what Optimem calls "AFOC", which is an auto-focusing procedure on the laser beam. The problem is that this procedure takes nearly a full second, and you have no control over when it occurs and cannot prevent it. Our solution has been to provide sufficient buffering space to withstand a break in data transfer to the disk of at least the duration of an AFOC. This seems to happen rarely, possibly once a day. Optimem indicates that it is to some extent a function

of duty cycle, happening less often the more the disk is used. On a number of occasions during data acquisition, this function was heard and seen to occur. There would be a short lapse in the reporting of buffers being written, the disk head would make a couple of coarse seeks, and then the quickened reporting of a few buffer writes as the system caught up. The use of multiple and large data buffers permits this to happen without loss of data, but in fact requires that there be a slight degradation in the guaranteed maximum continuous write rate.

Optimem is continually upgrading the firmware in their drives. These new versions have so far been supplied free of charge. Hardware changes have been made as well, 2 of which have required return shipment to the factory. They too have been no-cost. They have just released an upgrade to the FIFO buffer (from 4k to 64k), in the drive that may improve the performance under some conditions. It will cost about $2000. Generally, they have been helpful to us over the phone and have supplied diagnostic software they have written for various host adapters that was helpful to us early in our development program.

Despite the modest rates at which we took data during the PRUDEX experiment, (typically storage rates of 56 kbytes/s), it was possible to determine, by watching bus activity with an oscilloscope, that it took approximately .15 sec to write 64 kbytes of data. This implies that the drive was in fact writing at near maximum sustained rates since the buffer is only 4k and a track is 25k. This also confirmed that the host adapter can supply data at least as fast as the disk can take it, insuring that no rotational latency is incurred during the writing of a buffer. This condition is typically referred to as "interleave of 1".

Initially, during software development, there were problems writing buffers greater than 4k in length. It was difficult to determine whether the fault was in our software, the host processor, the NCR host adapter, or in the drive itself. The problem vanished when the host system was configured such that the acquisition program executed out of local-bus memory and only went out to the multibus for I/O operations. This way, except for I/O, the SCSI host adapter had only to share multibus bandwidth with the interrupt routine that transferred incoming data to system memory residing on multibus. Timely interrupt servicing is assured by limiting the contiguous period that the host adapter can keep the bus before it must release it for at least one cycle. This allows the host processor to get time on the bus to fetch incoming data. (Once the host gets the bus, it can lock all other masters out manually, despite its low priority.)

With the "smart" buffered GRA interface card in place, the process is slightly different. Incoming data is buffered on the GRA interface directly. When one segment of the buffer is full, the next is used for new data and the full one is accessed by the SCSI host adapter as system memory space. The host is interrupted by the GRA interface and initiates a transfer to the Optical disk via the host adapter.

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4.   Related information:

ODAS is housed in 2 to 4 rack mount packing cases, each consisting of a
25" rack box within a 2nd weather-tight shipping case. The two parts are
separated by 2" of foam all around. Most items in each pack rest on shelves
and are shipped with foam padding on all sides. They are not fastened, to the
front of the rack but instead are simply constrained on all sides by foam,
some of which is removed prior to operation for cooling.

We have shipped electronic equipment to the Arctic environment many
times. Our packing technique is not glamorous but has been effective. We use
3/4" plywood boxes with steel, perforated angle edges, fastened with bolts.
Everything is packed in soft foam, starting with a 2" lining inside the boxes.

The shipping sequence this year was perhaps a bit more rigorous than most
in that after a cross-country truck journey, the boxes were piece-by-piece
combined with another shipment on a flatbed trailer. This trailer went by
boat to Valdez, AK, then was driven to Prudhoe Bay. The 800 mile journey from
Fairbanks to Prudhoe is on a gravel road that is at times both rough and
dusty. After sitting in -40 degree temperatures at Prudhoe for a week or so,
all boxes were flown to the camp site 130 miles out on the ice in small fixed
wing aircraft, and manually unloaded.

We are careful to minimize thermal shock to equipment when setting it up
in a heated hut. In the case of optical media or, magnetic tape. this is
especially true. The only non-standard temperature related specification
Optimem cites for their drives and media is a rate of change of 10 degrees
Celsius per hour.

We anticipate the next field use of ODAS to be in early 1989. Some
modifications to software will be made between now and then but data formats
are expected to remain as described in this report. It is likely that a
second computer with somewhat more processing power than the Intel 310 will be
taken for modest field analysis of data. This second machine will connect to
the SCSI bus in parallel with the Intel 310 for direct access to data.

Upon return from the field, data disks will be read and processed by a
microVAX II system running the Ultrix operating system.   One or more Optimem
drives will be connected directly to the VAX system via an Emulex Mass Storage
Control Protocol (MSCP) to SCSI host adapter board.

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Greg Duckworth at BB&N, Cambridge, Ma, contributed ideas to the development of the optical disk formats described herein. Arthur Baggeroer of MIT was the chief scientist during PRUDEX 87. Both have been continually helpful with guidance for our acquisition system developments.

Ken Prada at W.H.O.I. has been generously helpful with insight to use of the "C" programming language during the development of software for this system.

References

Optimem 1000 SCSI Interface Manual, Rev F (OPT1.4), October 1985

Optimem 1000 Optical Disk Drive OEM Manual, Rev 4, April 1985

NCR ADP-32, SCSI Host Adapter, User's Guide, February 1984

American National Standards Institute (ANSI) Small Computer System Interface (SCSI) document ANSI X3.131-1986

American National Standards Institute (ANSI) IEEE Standard Microcomputer System Bus (MULTIBUS) IEEE Std 796-1983

iSBC 86/14 & 86/30 Single Board Computer Hardware Reference Manual, 1982, Intel Corp., 3065 Bowers Ave., Santa Clara, CA 95051

Optical Disk Drives & Manufacturers

Optimem 1000, 12", 1 gbyte/side
Optimem, 435 Oakmead Parkway, Sunnyvale, CA 94086
Tel: 415 961 1800

Hitachi OD-301A, 12", 1.31 gbyte/side
Hitachi America, Ltd., 950 Elm Ave., Suite 100, San Bruno, CA 94066
Tel: 415 872 1902

LaserDrive LD-33, 5.25", 350 mbyte/side
LaserDrive 1200, 12", 1 gbyte/side
LaserDrive Limited, 1101 Space Park Drive, Santa Clara, CA 95054
Tel: 408 970 3600

APX-3000, 5.25", 122 mbyte/side
Maximum Storage Inc., 5025 Dentennial Blvd, Colorado Springs, CO 80919
Tel: 303 531 6888

ISI 525 WC, 5.25", 115 mbyte/side
ISI 525 GB, 5.25", 550 mbyte/side
Information Storage Inc.,2768 Janitell Road, Colorado Springs, CO 80906
Tel: 303 579 0460

Alcatel GD1001, 12", 1 gbyte/side
Alcatel Thomson Gigadisc Inc.,470 Totten Pond Rd,Waltham, MA 02154
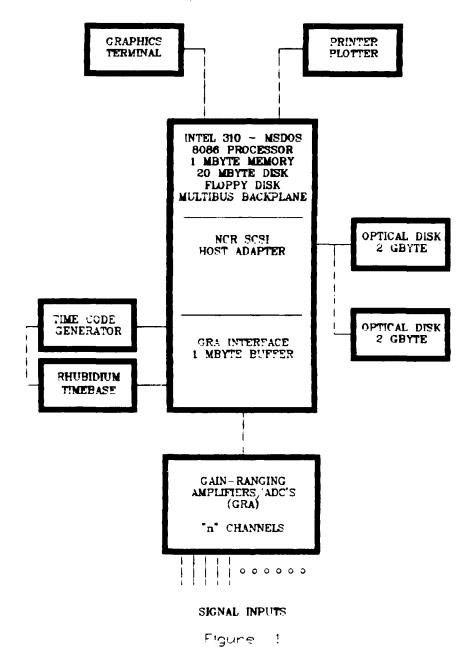Tel: 617 890 2534

IBM 3363, 5.25", 200 on single side
for IBM System/2

Sony WDD-3000, 12", 1.6 or 1.05 gbyte/side
Sony Corp. of America, Sony Drive, Park Ridge, NJ 07656
Tel: 201 930 6025

KOM USA
3rd party vendor offering hardware/software package connecting the Optimem
drive and others to VAX/VMS systems
14180 W.78th St, Suite 120, Eden Prairie, MN 55344
Tel: 1 800 267 0443

W.H.O.I. OPTICAL DISK BASED ACQUISITION SYSTEM
(ODAS)   1987

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  ┌──────────────┐              ┌──────────────┐
  │  GRAPHICS    │              │  PRINTER     │
  │  TERMINAL    │              │  PLOTTER     │
  └──────────────┘              └──────────────┘

          ┌──────────────────────────┐
          │  INTEL 310 – MSDOS        │
          │  8086 PROCESSOR           │
          │  1 MBYTE MEMORY           │
          │  20 MBYTE DISK            │
          │  FLOPPY DISK              │
          │  MULTIBUS BACKPLANE       │
          ├──────────────────────────┤     ┌──────────────┐
          │                          │     │  OPTICAL DISK │
          │      NCR SCSI            │     │  2 GBYTE     │
          │      HOST ADAPTER        │     └──────────────┘
          ├──────────────────────────┤
┌──────────┐                        │     ┌──────────────┐
│TIME CODE │                        │     │  OPTICAL DISK │
│GENERATOR │    GRA INTERFACE       │     │  2 GBYTE     │
└──────────┘    1 MBYTE BUFFER      │     └──────────────┘
┌──────────┐                        │
│RHUBIDIUM │                        │
│TIMEBASE  │                        │
└──────────┘  └──────────────────────┘

              ┌──────────────────────┐
              │  GAIN-RANGING        │
              │  AMPLIFIERS/ADC'S    │
              │  (GRA)               │
              │                      │
              │  "n" CHANNELS        │
              └──────────────────────┘
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SIGNAL INPUTS

Figure 1

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16. Abstract (Limit: 200 words)

This is a report on the use of one vendor's optical disk system for the archiving of data in the field. Two Optimem 1000 units are part of an acquisition system used by the Arctic acoustics groups at the Woods Hole Oceanographic Institution and the Massachusetts Institute of Technology during an ice-camp based experiment conducted during March of 1987 north of Alaska, (PRUDEX). Data recording and disk directory formats developed specifically for continuous recording of multichannel digital data are described as well as the acquisition system itself. A brief overview of available optical disk drive systems and their applicability to use in the field for storage of large volumes of data is given.

17. Document Analysis   a. Descriptors

1. acoustic data acquisition
2. optical disk
3. Arctic acoustics

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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